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Vision 2023: Forecasting Turkey's natural gas demand between 2013 and 2030

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A B S T R A C T

Natural gas is the primary source for electricity production in Turkey. However, Turkey does not have indigenous resources and imports more than 98.0% of the natural gas it consumes. In 2011, more than 20.0% of Turkey's annual trade deficit was due to imported natural gas, estimated at US$ 20.0 billion. Turkish government has very ambitious targets for the country's energy sector in the next decade according to the Vision 2023 agenda. Previously, we have estimated that Turkey's annual electricity demand would be 530,000 GWh at the year 2023. Considering current energy market dynamics it is almost evident that a substantial amount of this demand would be supplied from natural gas. However, meticulous analysis of the Vision 2023 goals clearly showed that the information about the natural gas sector is scarce. Most importantly there is no demand forecast for natural gas in the Vision 2023 agenda. Therefore, in this study the aim was to generate accurate forecasts for Turkey's natural gas demand between 2013 and 2030. For this purpose, two semi-empirical models based on econometrics, gross domestic product (GDP) at purchasing power parity (PPP) per capita, and demographics, population change, were developed. The logistic equation, which can be used for long term natural gas demand forecasting, and the linear equation, which can be used for medium term demand forecasting, fitted to the timeline series almost seamlessly. In addition, these two models provided reasonable fits according to the mean absolute percentage error, MAPE %, criteria. Turkey's natural gas demand at the year 2030 was calculated as 76.8 billion m^3 using the linear model and 83.8 billion m^3 based on the logistic model. Consequently, found to be in better agreement with the official Turkish petroleum pipeline corporation (BOTAS) forecast, 76.4 billion m^3, than results published in the literature.

Contents

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1. Introduction

Starting from the foundation of the republic in 1923, Turkish economy was under strict government control until 1980s. However, under the leadership of Prime Minister Mr. Turgut Ozal the country undertook a major reform programme to open its insulated state-system to a more private-sector dominated export-led economy. This liberalisation immediately showed its effects in more economic freedom and a boosting economic growth. Between 1981 and 1984, Turkey's average annual gross domestic product (GDP) growth rate was 5.1% [1]. Coupling industrialization with rapid population growth and an open-market economy Turkey's energy demand inevitably showed an exponential increase in the meantime. Unfortunately, Turkey did not have enough indigenous energy sources to supply this demand gap.

In 1984, in order to secure additional energy sources, Turkey's first international natural gas agreement was signed with the former Union of Soviet Socialist Republics (USSR). Following this agreement the first main natural gas transmission line was built, which is coming from the Bulgarian border and extending to Ankara. In the following 8 years five cities along this route: Istanbul, Izmit, Bursa, Eskisehir, and Ankara were all linked to the natural gas distribution line [2]. Since then, natural gas has been predominantly used in Turkey for the following two purposes.

Currently, natural gas is used as the premier residential heating and cooking fuel. Until, 1987 in Turkish cities residential heating was mainly supplied by coal and fuel oil. In addition, coal gas, which was delivered through the city grid, and liquefied petroleum gas (LPG), which was delivered in small containers, were used for cooking. This caused significant air pollution, smoke and soot formation in big Turkish cities. Providentially, this was largely dispelled after the implementation of natural gas except for low income areas where residents still use coal for domestic heating.

As Turkey's economy kept on growing the thirst for energy continued to expand at unprecedented rates. In 1985, Turkey's annual electricity generation was only 34,218 GWh, which increased to 86,248 GWh in 1995, 161,956 GWh in 2005, and 229,395 GWh by the end of 2011 [3]. In early 1980s, this demand was predominantly supplied from lignite, fuel oil, and hydropower. However, as natural gas put into service Turkey's energy market dynamics changed radically. In 1985, the share of natural gas in Turkey's annual gross electricity generation was only 0.2%, which exponentially rose to 19.2% in 1995, 45.3% in 2005, and finally 45.4% in 2011, as shown in Table 1 [4]. Accordingly, the major exploitation of natural gas in Turkey has been for electricity generation [5].

In spite of this, Turkey does not have indigenous natural gas resources and must import nearly all it consumes. Approximately, 98.0% of Turkey's natural gas demand was imported in the year 2011. Consequently, there is a price for this superfluous dependency. More than half of Turkey's current trade deficit is due to imported energy sources, estimated at approximately US$50.0 billion in 2011 [6,7]. According to the minister of energy and natural resources Mr. Taner Yildiz, Turkey spent US$20.0 billion to imported natural gas at the year 2011 [8]. This was equal to more than 20.0% of Turkey's annual trade deficit. As for now, Turkey can easily offset this natural gas import bill. Mainly due to the country's thriving economy.

This has been achieved by several major economic reforms placed on the monetary system after the devastating economic crisis of 2001. Between 2001 and 2012, Turkish economic system, under the leadership of Prime Minister Mr. Recep Tayyip Erdogan, was tested by the global economic crisis of 2008 and the recession in the aftermath. Turkish economy passed both these test with flying colours. As a result, today's Turkey has one of the most

Table 1
Annual development of Turkey's gross electricity generation by share of primary energy sources, between 1985 and 2011 (%) [4].

	UNIT, %											
Years	*Hard coal*[*]	*Lignite*	*Fuel oil*	*Diesel oil*	*LPG*	*Naphta*	*Renewable and Wastes*	*Natural gas*	*Total, thermal*	*Total, hydro*	*Geothermal +wind*	*Total*
1985	2.1	41.8	20.5	0.2	0.0	0.0	0.0	0.2	64.8	35.2	0.0	100.0
1986	2.0	47.0	17.5	0.1	0.0	0.0	0.0	3.4	70.0	29.9	0.1	100.0
1987	1.4	38.4	12.2	0.2	0.0	0.0	0.0	5.7	57.9	42.0	0.1	100.0
1988	0.7	25.3	6.8	0.1	0.0	0.0	0.0	6.7	39.6	60.3	0.1	100.0
1989	0.6	38.3	8.1	0.1	0.0	0.0	0.0	18.3	65.4	34.5	0.1	100.0
1990	1.1	34.0	6.8	0.0	0.0	0.0	0.0	17.7	59.6	40.2	0.2	100.0
1991	1.7	34.1	5.6	0.0	0.0	0.0	0.1	20.8	62.3	37.6	0.1	100.0
1992	2.7	33.8	7.8	0.0	0.0	0.0	0.1	16.0	60.4	39.5	0.1	100.0
1993	2.4	29.7	7.0	0.0	0.0	0.0	0.1	14.6	53.8	46.1	0.1	100.0
1994	2.5	33.5	7.1	0.0	0.0	0.0	0.1	17.6	60.8	39.1	0.1	100.0
1995	2.6	29.9	6.4	0.3	0.0	0.0	0.3	19.2	58.7	41.2	0.1	100.0
1996	2.7	29.3	6.5	0.4	0.0	0.0	0.2	18.1	57.2	42.7	0.1	100.0
1997	3.2	29.6	6.3	0.5	0.1	0.0	0.3	21.4	61.4	38.5	0.1	100.0
1998	2.7	29.5	6.6	0.3	0.2	0.1	0.2	22.4	61.9	38.0	0.1	100.0
1999	2.7	29.1	5.6	0.6	0.2	0.5	0.2	31.2	70.1	29.8	0.1	100.0
2000	3.1	27.5	6.0	0.8	0.3	0.4	0.2	37.0	75.2	24.7	0.1	100.0
2001	3.3	28.0	7.2	0.7	0.1	0.4	0.2	40.4	80.3	19.6	0.1	100.0
2002	3.1	21.7	7.4	0.2	0.0	0.7	0.1	40.6	73.8	26.0	0.2	100.0
2003	6.1	16.8	5.8	0.0	0.0	0.8	0.1	45.2	74.8	25.1	0.1	100.0
2004	7.9	14.9	4.4	0.0	0.0	0.6	0.1	41.3	69.2	30.6	0.2	100.0
2005	8.1	18.5	3.2	0.0	0.0	0.2	0.1	45.3	75.4	24.4	0.2	100.0
2006	8.0	18.4	2.4	0.0	0.0	0.0	0.1	45.8	74.8	25.1	0.2	100.0
2007	7.9	20.0	3.4	0.0	0.0	0.0	0.1	49.6	81.0	18.7	0.3	100.0
2008	8.0	21.1	3.6	0.1	0.0	0.0	0.1	49.7	82.8	16.8	0.5	100.0
2009	8.5	20.1	2.3	0.2	0.0	0.0	0.2	49.3	80.6	18.5	1.0	100.0
2010	9.1	17.0	1.0	0.0	0.0	0.0	0.2	46.5	73.8	24.5	1.7	100.0
2011	11.9	16.9	0.4	0.0	0.0	0.0	0.2	45.4	74.8	22.8	2.4	100.0

[*] Including imported coal and asphaltite.

Table 2
Vision 2023 targets for Turkey's energy sector [11].

Area	Target
Installed power	125,000 MW
Share of renewable sources in power generation	30.0%
Transmission lines	60,717 km
Power distribution unit capacity	158,460 MVA
Electricity loss-theft vie smart grids	5.0%
Natural gas storage capacity	5.0 billion m^3
Energy stock exchange	Established
Nuclear power	8 reactors with a capacity of 10,000 MW
Nuclear power (under construction)	4 reactors with a capacity of 5,000 MW
Coal power	18,500 MW
Hydropower	Full utilisation
Wind power	20,000 MW
Solar power	3,000 MW
Geothermal power	600 MW

Table 3
Turkey's annual natural gas import, between 1987 and 2011, billion m^3 [12].

Year	Natural gas, billion (m^3)
1987	0.4
1988	1.1
1989	3.0
1990	3.2
1991	4.0
1992	4.4
1993	5.0
1994	5.4
1995	6.9
1996	8.0
1997	9.9
1998	10.2
1999	12.4
2000	14.8
2001	16.4
2002	17.6
2003	21.2
2004	22.2
2005	27.0
2006	30.7
2007	36.5
2008	37.8
2009	33.6
2010	32.5
2011	39.7

resilient economies in the world, and has the highest GDP growth rate amongst all European Union member and associate states [9].

Adding a vibrant young population on top of this strong economy Turkish government recently announced a series of ambitious economic plans under the Vision 2023 agenda. The overall aim is to become one of the world's ten largest economies with a gross domestic product of US$ 2.0 trillion; a foreign trade volume in excess of US$ 1.0 trillion; per capita income to reach US$ 25,000; and unemployment to decline to 5.0% until the year 2023 [10]. The centennial founding of the Turkish Republic. Accordingly, energy is by far the most important topic under the Vision 2023 agenda, and the Turkish government has grandiose targets for this sector as shown in Table 2 [11].

However, meticulous analysis of the Vision 2023 goals clearly showed that there is no detailed information given about the natural gas market of Turkey. This is quite shocking considering natural gas as the premier energy source for electricity generation in Turkey. The only information was given about the projected natural gas storage capacity of 5.0 billion m^3 in 2023. Along with it was underlined that Turkey's dependence on imported natural gas would be a major weakness of the energy market in the next decade. As a result, the aim of this study was to provide this lacking information, and generate sound forecast model(s) for Turkey's natural gas demand between 2013 and 2030 under the sight of Vision 2023 goals.

Table 4
Turkey's international natural gas purchase contracts [14].

Contract	Quantity*	Duration (Year)	Years of gas delivery commencement
Russian Federation (Westward) **	6	25	1987
Algeria (LNG)	4	20	1988
Nigeria	1.2	22	1999
Iran	10	25	2001
Russian Federation (Blue stream)	16	25	2003
Russian Federation (Westward)	8***	23	1998
Turkmenistan	16	30	–
Azerbaijan	6.6	15	2007

* Denotes the plateau value (billion m3/year).
** Contract has terminated as of 31.12.2011.
*** The 4 billion m^3/year portion of the purchase-sell contract of BOTAS dated 18.02.1998 has been transfered under Temporary Artıcle 2 of the Law no. 4646.

2. Theory and literature review

2.1. Natural gas demand in Turkey

In 1987, when the first pipeline was opened, annual natural gas demand in Turkey was only 0.4 billion m^3. As Turkey's economy grow natural gas demand increased exponentially and reached to staggering 39.7 billion m^3 in 2011. The timeline series of Turkey's natural gas import, between 1987 and 2011, is reported in Table 3 [12]. Currently, most of this massive amount of natural gas is transmitted by land and underwater pipelines, and a small portion from sea via supertankers in the form of liquefied natural gas (LNG). In addition, existing and under construction natural gas pipelines bolster Turkey as a transit hub for natural gas between Asia and Europe.

According to Turkey's Energy Market Regulatory Authority (EMRA), approximately 45.0% of the country's annual electricity demand is supplied from natural gas [13]. Considering that nearly all the natural gas is imported and the limited storage capacity any problem with the delivery of natural gas will have devastating effects on the Turkish economy. In terms of energy security this presents a major vulnerability and a soft spot in the macroeconomic balances. In addition, any sharp price increase in the natural gas could easily worsen Turkey's trade deficit and hinder the booming economic growth. In order to overcome these "what ifs" and worst case scenarios occurring in the near future Turkey signed multiple sales and purchase contracts with the Russian Federation, Algeria, Nigeria, Iran, Turkmenistan, and Azerbaijan in the last decade. Details about these contracts are given in Table 4 [14].

Although these contracts have variable durations up to 30 years, as Turkey's economy grow its thirst for natural gas also increases. As a consequence, Turkey's dependency on natural gas could pass the point of no return in the next decade. Therefore, it is pretty clear that we must generate reliable forecasting models to deliberately monitor Turkey's natural gas demand.

2.2. Studies on forecasting energy and natural gas demand in Turkey

In this section, the work in the literature were analysed from macro to micro scale in order to find a solid starting point for the consequent modelling studies. At macro scale gross domestic product, population, and price of fuel are generally the most common independent variables used in economic modelling of energy demand in a country. In Turkey, energy demand forecasting has been carried out by the Ministry of Energy and Natural Resources (MENR) in accordance with the targets given by the State Planning Organization (SPO) since 1984. These, energy projections are made by taking into account various factors including energy conservation, development, industrialization, urbanization, technology, and revised each year in the light of the performance over the past year [15]. The estimation of energy demand based on the aforementioned economic indicators can be modelled using various forms of equations. The most common statistical and econometric techniques used for forecasting energy demand in Turkey are reported in Table 5.

In the literature there are also a few studies that solely focus on Turkey's natural gas sector and consequent demand forecasting [2,16–22]. However, most of the work in this field has been given as subsections in the papers, which focus on Turkey's or the regions overall energy market dynamics and/or subsequent total demand forecasting [23–36]. Out of these models the most common method that has been used to forecast medium to long term energy demand are Autoregressive Integrated Moving Average (ARIMA), seasonal ARIMA (SARIMA) and Model for Analysis of Energy Demand (MAED) [37,38]. Similarly, the most recent analysis on Turkey's natural gas demand forecasting was carried out by Erdogdu using an ARIMA model for a time span between 2008 and 2030 [17]. Amongst these various statistical and econometric models none has been constantly used to forecasting Turkey's energy demand. Unfortunately, due to forecasts generated using these models have consistently predicted higher values than the actual energy consumption. Basically because the sole purpose of these models is to generate results with the least error between the predictions and actually observed values [39]. As a result, such models crucially lack connectionism and subsequent practicality.

Instead of using the same modelling tools, which clearly lack accuracy and originality, over and over again we must generate new tools for energy demand forecasting. In that context, semi-empirical models based on both econometric and statistical parameters could provide such a solution. It has been reported that simple linear, and exponential models can be successfully used for energy demand forecasting, which typically provide a straightforward means of directly calculating forecasts [40]. In two recent studies by the author of this paper electricity consumption and biogas generation in Turkey, between 2010 and 2023, were also estimated via semi-empirical models generated based on demographics and gross domestic product [41,42]. In this study, we have continued in the same direction by implementing two new semi-empirical models with the aim to generate accurate forecasts for Turkey's natural gas demand between 2013 and 2030. Details about the modelling studies are given in the next section.

Table 5
Energy demand forecasting studies about Turkey.

Model	References
Ant colony optimization (ACO)	[68]
Artificial neural networks (ANN)	[69–72]
Autoregressive integrated moving average (ARIMA)	[27,38]
Forward feeding back-propagation (BP)	[73]
Genetic algorithms (GA)	[15,74]
Nonlinear regression (NLR)	[75]
Grey prediction with rolling mechanism (GPRM)	[76]
Simple linear regression (LR)	[62,77]
Seasonal autoregressive integrated moving average (SARIMA)	[78]
Structural Time Series Model (STSM)	[79]
Support vector regression (SVR)	[80]
Swarm intelligence (SI)	[39]

3. Results and discussion

3.1. Estimation of maximum attainable natural gas demand per capita in Turkey

At the beginning it was decided to build the forecast models using per capita natural gas demand data, which also would be a function of gross domestic product (GDP) at purchasing power parity (PPP) per capita. Generally, increase in energy demand implies higher economic status of a country. Many studies have shown that countries with high GDP (PPP) per capita also have high electricity consumption per capita [43–48]. Since 2001, electricity consumption in Turkey has been increasing at unprecedented rates due to the country's boosting economic growth [42]. In the intervening time, it was also observed that natural gas demand has increased exponentially. This is evident, because natural gas is the primary source for electricity generation in Turkey. However, we must all know that Turkey's natural gas demand is not going to increase forever. In the next 20 to 30 years, as Turkey reaches to a certain level of economic development natural gas demand per capita will first decelerate, and then settle like other macroeconomic parameters. This is the primary rule of market settlement. After stagnation natural gas demand per capita even might show a slight decrease. This would be similar to what we have observed in the last decade in some European Union (EU) countries [49]. As a result, natural gas demand in Turkey will follow a logistic pattern with deceleration by the end of the first half of this century. Thus modelling studies on natural gas demand in Turkey must be based on this fact rather than using statistical time series analysis tools such as ARIMA, SARIMA, etc., which mostly generate a precise fit but crucially lack the basic rationale of modelling.

In the year 2011, Turkey's population was 74.3 million people [50] and the annual natural gas demand was approximately 39.7 billion m^3 [12]. Thus, the natural gas demand per capita in the same year was calculated as 535 m^3. It is expected that GDP (PPP) per capita in Turkey will reach to US$ 25,000 by the year 2023 [10]. Today, South Korea in Asia, Italy and Spain in the EU have slightly higher GDP (PPP) per capita at US$ 30,000 and almost similar natural gas demands to Turkey [51]. In addition, these are the economies, which Turkish government aims to reach and luckily surpass according to the Vision 2023 agenda.

In the year 2011, natural gas demand in Italy, South Korea and Spain were 71.3, 46.6, and 32.1 billion m^3 [52]. Whilst, the average population was 61.0, 48.7, 46.7 million people, respectively [53]. Using these data, natural gas demand per capita was estimated at 1,165 m^3 in Italy, 955 m^3 in South Korea, and 680 m^3 in Spain at the year 2011. However, before going any further, it must be emphasized that since the aftermath of the global recession in 2008 Spain's economy is in one of the worst crisis that the country ever faced. As a result, like all macroeconomic indicators, Spain's natural gas demand showed a steep decrease in the last 5 years. Therefore, to make sensible judgement we have decided to use Spain's natural gas demand per capita at the year 2008 for comparison. When the population was 45.3 million people and natural gas consumption at 38.6 billion m^3 [52,53], making Spain's natural gas demand per capita at 855 m^3. Thus the

average natural gas demand per capita for these three countries was estimated as 990 m^3.

As a result, it would be reasonable to assume Turkey's natural gas demand per capita would reach to 990 m^3 between 2030 and 2035. When, the country's GDP (PPP) per capita reaches to US$ 30,000 and the socio-economic development to that of Italy, Spain and South Korea. This figure was used as the maximum attainable natural gas demand of Turkey by 2040 in all the following calculations. Next, Turkey's population change in the meantime must be estimated to forecast the annual natural gas demand, in m^3.

3.2. Estimation of population change in Turkey between 2013 and 2030

The Turkish Statistical Institute (TurkStat) monitors population change in Turkey and use a Malthusian based approach in population growth projections. Likewise, a modified Malthusian model was used in this study to predict the mid-year population of Turkey, between 2012 and 2030, as shown in Eq. (1).

$$P_t = P_{t-1} e^{k_p \cdot t} \tag{1}$$

In Eq. (1), t is time of interest in years, P_t is the estimated population at year t, P_{t-1} is the population at the previous year of concern, and k_p is annual population growth rate constant. Using mid-year population data, between 1987 and 2011 [50], and TurkStat's k_p values generated from address based population system [54], Turkey's population projection between 2012 and 2030 were evaluated and tabulated in Table 6.

It is clearly seen from Table 6 that Turkey's population growth will significantly slow down in the next two decades. It was estimated that the country's population will be 81.8 million in 2020, 84.1 million at the centennial of the republic, and finally 88.5 million in 2030. Hence, Turkey's population would definitely not be over 100 million in 2020 as reported by Demirbas in an earlier study on Turkey's energy demand analysis [31]. This clearly shows the utmost importance of the accuracy of population data for energy demand forecasting. Next is the development of the natural gas demand forecasting models.

3.3. Forecasting natural gas demand in Turkey between 2013 and 2030

Siemek and co-workers [55] combined previous studies of Laherrere and Sornette [56], Hubbert [57,58] and by Al Fattah et al. [59], proposing a deterministic model based on the logistic growth curve to forecast natural gas consumption in Poland, which took into account the macroeconomic balances and the economic cycles affecting the country [60]. Similarly Forouzanfar and co-workers used a logistic based approach is to forecast the natural gas consumption for residential as well as commercial sectors in Iran [61]. On the other side, Yumurtaci and Asmaz used simple linear regression to generate Electric Energy Demand of Turkey for the year 2050 [62]. Similarly, Aras and Aras used a linear model to forecast residential natural gas demand in Turkey [18].

Providentially, this can be augmented via using GDP (PPP) and population data. In this study, natural gas demand forecasting in Turkey, between 2013 and 2030, was carried out using (i) a modified logistic equation following the works of Laherrere and Sornette and Siemek et al. [55,56] as shown in Eq. (2), and (ii) a modified linear equation following the work of Aras and Aras [18] as shown in Eq. (3).

$$q_t = \left[\frac{q_{\max}}{1+e^{-a\cdot(t-t_{\max})}}\right]\cdot P(t)+\varepsilon_t \tag{2}$$

Table 6
Mid-year population data and projections for Turkey, between 1987 and 2030.

Year	Population (million)	References
1987	52.4	[41,50,54]
1988	53.3	
1989	54.2	
1990	55.1	
1991	56.1	
1992	57.0	
1993	57.9	
1994	58.8	
1995	59.8	
1996	60.7	
1997	61.6	
1998	62.5	
1999	63.4	
2000	64.3	
2001	65.1	
2002	66.0	
2003	66.9	
2004	67.7	
2005	68.6	
2006	69.4	
2007	70.2	
2008	71.1	
2009	72.1	
2010	73.0	
2011	74.0	
2012	74.9	Current study
2013	75.8	
2014	76.7	
2015	77.6	
2016	78.5	
2017	79.3	
2018	80.2	
2019	81.0	
2020	81.8	
2021	82.6	
2022	83.3	
2023	84.1	
2024	84.7	
2025	85.4	
2026	86.1	
2027	86.7	
2028	87.3	
2029	87.9	
2030	88.5	

$$q_t = [q_0 + b\cdot(t-t_0)]\cdot P(t)+\varepsilon_t \tag{3}$$

In Eqs. (2) and (3), t is time in years; t_0 is the reference year, which is 1987 when natural gas was first brought to Turkey; $q(t)$ is the natural gas demand at year t in m^3; q_0 is the natural gas demand per capita at the reference year in m^3, which was determined as 8.4 m^3 using the data from Tables 3 and 6; q_{max} is the maximum attainable natural gas demand per capita in m^3, which was estimated at 990 m^3 in the previous section; t_{max} is time in years when $q(t_{max})$ is equal to half of q_{max}; $P(t)$ is the population at the year t; and finally a and b are unknown coefficients, and ε_t is the random error term.

The overall use of natural gas in OECD countries is projected to increase 2.4% annually until 2020 [16]. Similarly, natural gas demand for electricity production in Turkey would increase 2.7% annually until 2030 [63]. In Turkey, approximately 75.0% of the natural gas is consumed for electricity generation and for other industrial applications, whereas the remaining 25.0% is used residential heating [13]. Therefore, Turkey's annual natural gas demand increase until the year 2030 was calculated as $0.75\times2.7\%+0.25\times2.4\%=2.6\%$. Thus the coefficient b in Eq. (2) is reverse engineered to be 20.530.

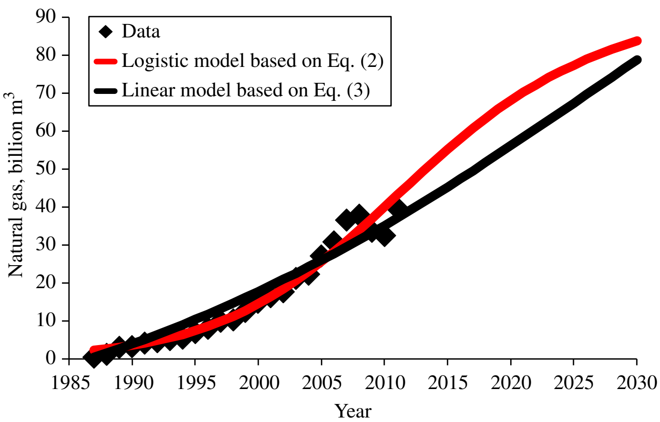

Fig. 1. Timeline series of natural gas demand in Turkey [12] and forecast models generated using Eqs. (2) and (3).

Using natural gas demand per capita data, between 1987 and 2011 given in Tables 3 and 6, and the statistical functions provided by the software SigmaPlot 11 and Microsoft Excel 2007, t_{max} and a were calculated as the year 2008 and 0.156, respectively. Finally, by substituting the coefficients and constants into Eqs. (2) and (3) and utilizing the mid-year population data given in Table 6 Turkey's annual natural gas demand forecasts between 2012 and 2030 were estimated and shown in Fig. 1.

Although, both natural gas demand per capita models fitted almost seamlessly to the timeline series we must also verify their accuracy. This was achieved by using statistical tools and comparing the forecasts with other demand projections tabulated in the literature.

3.4. Accuracy of the modelling results

The accuracy of the forecasting models are compared with the timeline series using the following indices based on the analogy by Lee and Tong [64]. The root mean square of error, RMSE, which compares the forecasted values with actual time series data shown in Eq. (4) is the first index used. Where, F_t is the forecasted value at the year t, A_t denotes the actual value at year t. The second index is the mean absolute percentage error, MAPE %, which statistically indicates the accuracy of the forecasted values with the actual data as shown in Eq. (5).

$$RMSE = \sqrt{\sum_{t=1}^{N} \frac{(F_t - A_t)^2}{N}} \quad (4)$$

$$MAPE\,\% = \frac{1}{N}\sum_{t=1}^{N}\left|\frac{F_t - A_t}{A_t}\right| 100\% \quad (5)$$

The accuracy of forecasts is evaluated based on error estimation, thus the smaller the value of RMSE and MAPE, the better the forecast is [65]. The scale of judgement based on MAPE criteria developed by Lewis shown is used for model evaluation [66,67]. Also the goodness of fit is measured via the estimation coefficient of determination, R^2. The RMSE, MAPE %, and R^2 values associated with the linear and logistic models are given in Table 7. According to the MAPE index and R^2 values both models generated reasonable forecasts. However, the logistic model shown in Eq. (2) is considered as a better fit. At this point it must be emphasized that although the modified linear model provided high level of accuracy it should be used for medium term natural gas demand forecasting of Turkey, till 2035, due to its sequential nature. However, the logistic model can be used for long term forecasting probably up to 2050.

Table 7
RMSE, MAPE (%), and R^2 values of natural gas demand forecasting models.

Parameter	Logistic model, Eq. (2)	Linear model, Eq. (3)
RMSE	2.348	3.257
MAPE (%)	31.335	36.341
R^2	0.961	0.919

Table 8
Turkey's natural gas demand forecasts between 2013 and 2030, billion (m^3).

Year	Official BOTAS forecast [81]	Kilic's forecast [16]	Erdogdu's forecast [17]	Linear model, Eq. (3)	Logistic model, Eq. (2)
2013	–	–	51.2	40.4	49.3
2014	–	–	53.3	42.4	52.3
2015	56.2	66.6	55.3	44.4	55.2
2016	–	–	57.4	46.4	58.0
2017	–	–	59.5	48.5	60.7
2018	–	–	61.6	50.6	63.3
2019	–	–	63.7	52.7	65.7
2020	65.9	82.0	65.8	54.8	68.0
2021	–	–	67.9	57.0	70.2
2022	–	–	70.0	59.2	72.2
2023	–	–	72.0	61.3	74.1
2024	–	–	74.1	63.5	75.8
2025	70.5	–	76.2	65.7	77.4
2026	–	–	78.3	67.9	78.9
2027	–	–	80.3	70.1	80.3
2028	–	–	82.4	72.3	81.6
2029	–	–	84.4	74.6	82.7
2030	76.4	–	86.4	76.8	83.8

The MAPE index provides us to compare the models with the timeline series; however, we also need to compare the results with other forecasts given in the literature and shown in Table 8.

As can be seen from Table 8, both the linear and logistic model developed uniquely in this study was in a better agreement with the BOTAS's official forecasts than the models generated by Erdogdu [17] and Kilic [16]. It is clearly evident that ARIMA or other types of statistical modelling tools does not always provide a better estimation than the models that can be generated based on solid statistical, econometric and demographic parameters as shown in this study. Turkey's natural gas demand in the year 2030 was estimated at 76.8 billion m^3 with the linear model given in Eqs. (3) and 83.8 billion m^3 based on the logistic model in Eq. (2). Both are in better agreement with the official BOTAS forecast, 76.4 billion m^3, than the results reported in the literature.

4. Conclusion

To sum up, the results found in this study confirms that equations, based on generally accepted theories, and developed using the fundamental rules of econometrics, demographics and statistical analysis can be used to generate accurate forecasting models for natural gas demand. Instead of using the same modelling tools: ARIMA, SARIMA, etc., over and over again such models could provide both elasticity and precision. The linear model, Eq. (3), could further be used for forecasting medium term natural gas demand in other developing countries. Similarly, the logistic model, Eq. (2), could be used for long term demand forecasting both in developing and developed countries.

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